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## OBSERVATIONS ON MIRAGES.

By BERNARD B. SMYTH, Topeka.

Read before the Academy, at Manhattan, November 28, 1903.

MIRAGES are of two kinds—reflecting and refracting. They are both so well known I need not define them here. Both occur in western Kansas, where the air is clear and distant vision is possible. Reflecting mirage is again of two kinds, always more or less associated with refraction. The most noticeable form is the ground mirage, which always occurs in the heat of the day when the sun shines brightly and the air next the ground becomes superheated. A broad level or slightly depressed area is necessary for its best development. On such occasions the earth becomes invisible and the sky is reflected from the ground as from a sheet of water. The action of a slight breeze enhances the deception by causing waves on the surface of the mirage as on a lake of water. Small objects, as weeds on a slight elevation beyond the mirage, are magnified and distorted into trees and living forms, often appearing to move with great rapidity. This kind of mirage has been described so often I will not dwell upon it. I only mention a single occurrence that took place in Barton county, Kansas, during the summer of 1876. The Santa Fe railroad passed in front of my house, about one-third of a mile distant toward the south. My house, from which I viewed the phenomenon, stood on a slight eminence, raising me about fifteen feet above the prairie intervening between me and the railroad.

One afternoon, with the wind gentle from the southeast, a passenger-train came from the west, making no audible sound. The ground mirage was like a sheet of water or dense fog, reflecting the sky between me and the train so as to completely hide the ground, the wheels, and a depth of about a foot of the lower part of the cars. The entire train, very distinctly to be seen except its lower part, sailed along silently on top of the fog-like mirage as though floating through the air. No visible smoke just then came from the engine; no rumble of the train could be felt; and, except the faces at the windows and one or two persons standing on the platforms, there was no evidence of life and no activity. The whole presented a most remarkable sight—the silence of the train; the invisibility of its lower part; the quiet, majestic movement; the spectral appearance of the engine and cars—the whole made an impressive scene that lasted while the train was traveling nearly a mile, or say a little more than a minute. On reaching a point toward the wind, half a mile to the southeast, a gentle

rumble began to be felt and heard. The noise increased to a loud roar as the train sped away to the east and only ceased when the train stopped at Ellinwood, four miles distant. Even after the train started up again the rumble could be heard, though gradually growing fainter as the train neared Raymond, twelve or fifteen miles distant.

The other form of reflecting mirage is where objects on the earth are reflected into the sky. This is caused by the air becoming stratified. On such occasions distant objects in the observer's stratum are seen inverted in the sky, reflected at a very high angle of incidence and reflection from the surface of the stratum overhead. The angle of reflection on such occasions is usually  $89\frac{1}{2}$  degrees, or even more.

A far more important form of mirage—one that occurs always in clear, cold weather, and all over Kansas—is of the pure refracting kind. This usually occurs in the evening, at night, or in the morning, when the air is comparatively still and the cold air settles down into the valleys. On such occasions the cold air flows, like water, from its own gravity, down into the lower ground. The rate of flow, whenever noticed, is about 2 miles per hour. When the rate exceeds 4 miles per hour, the proper refraction of the rays of light is disturbed and the beauty of the vision is destroyed. I say "beauty of the vision," because it is always beautiful, grand, exalting, entrancing. To be able to see, when you are living in a broad, shallow valley, across the distant hills into another valley, and to see distinctly the houses, with the smoke arising gently from them, and to see the young groves and other large objects in their natural positions, when you know that the elevated prairie between you and the objects seen is at least 100 feet above your level, is exhilarating beyond conception.

For six years—from 1874 to 1880—I lived in Barton county, Kansas, and kept a weather record during all that time. Observations were recorded thrice daily on temperature, humidity, rainfall, wind direction and velocity, and clouds. On looking up my old record for notes concerning mirage, I find during winter, on an average of about twice a week, this note: "Mirage at sunrise." Notes like these: "Strong refracting and reflecting mirage at sunrise," etc., "mirage to north at sunrise," "mirage at sunset," "very strong mirage," etc., occur about once a month or less frequent. Ellinwood is in the middle of the Arkansas valley, about 10 feet above water-level in the river, with a horizon so low to the north and south and west that it seems like being on a dead-level prairie or an ocean of grass. Very low upland is to be seen northwest and east, and higher sand-dunes to the southwest. The first mirage of the refracting kind within my observation was in the fall of 1874, while teaching at Ellinwood.

The occasion was before sunrise on a calm, clear, frosty morning. The sight was most beautiful and inspiring. The land to the north

seemed to be raised slightly; and the high divide in Russell county, just south of the Smoky Hill river, and about 25 miles distant, was plainly to be seen above the ordinary horizon. Great Bend, to the west, was in plain view; though ordinarily only the tower of the court-house could be seen. Looking farther up the valley and somewhat to the south of Great Bend, the few houses at Pawnee Rock, 24 miles distant, could be seen and readily distinguished by the smoke rising from the chimneys. Some one said: "Look over toward the salt marsh." That was about 10 miles distant to the south. The few low sand-dunes between Ellinwood and the salt marsh dwindled into insignificance. A few houses in a group, with columns of smoke rising from the flues, a small grove of trees and a church or school-house could be seen. There were no houses on the salt marsh, and none in the sand-hills south of Ellinwood; nothing but a dugout or two and surely no schoolhouse. There were probably not less than twenty people standing in the streets of Ellinwood looking at the scene. Presently some one who had been to Stafford began to recognize places and declared he could identify various buildings. This though doubted at first was soon accepted. Then, for a few minutes, other houses and a church further west came into view. Judging from the position and direction the group of houses was considered to be the village of Zion Valley, a Mormon settlement then existing south of Rattlesnake creek, in Stafford county. Farther west only sand-hills could be seen.

The distance to Stafford in an air-line was 27 miles; to Zion Valley, 29 miles. The intervening highest ground in the direction of Stafford was about 80 feet above the level of the river at Ellinwood, 17 miles south of Ellinwood and 10 miles north of Stafford. Stafford itself was and is about 70 feet above the level of the Arkansas river at Ellinwood. The highest ground between Ellinwood and Zion Valley was about 100 feet above the Ellinwood level, 19 miles south of Ellinwood and 10 miles north of Zion Valley. These highest points are ordinarily hidden from view at Ellinwood, by dunes 50 to 70 feet high about 6 miles south of Ellinwood. The elevation of Zion Valley was about 110 feet above the Ellinwood level. And still, to all appearances, the hills and the town of Zion Valley scarcely looked higher than Stafford and the hills in front of it.

Considering the curvature of the earth and the height of the intervening hills, the necessary apparent elevation of Stafford above its normal position in order to be seen at Ellinwood would be about 490 feet, equivalent to an elevation of 12' of arc. This is equal to two-fifths the diameter of the full moon at rising. The elevation of distant objects appeared to be more than that; though probably was not. In fact, the entire horizon appeared to be elevated more than half the

diameter of the full moon, or about one-third of a degree. In about 20 minutes the sun came up; the air began to be tremulous with warmth and the unusual sights disappeared.

My homestead was at "Red Rocks," 4 miles west of Ellinwood, where the high table-land north of the Arkansas makes its closest approach to the river. This is the narrowest part of the valley in Kansas, being not more than 3 miles wide. This was a noted camping-place for Santa Fe freighters and emigrants. Wood and water were plentiful, especially the water. After two years' teaching at Ellinwood and Raymond, I built on a shelf of red Dakota sandstone near the base of the bluff and about 25 feet above a low part of the valley near by. My instrument shelter was on another shelf back of the house about 15 feet higher. My view from the house to the north was cut off by the bluff back of the house, the summit of which was 85 feet above the river; to the south was interrupted about 6 miles distant by barren sand-hills, probably 200 feet high, south of the river. The river itself was half a mile distant, and ran straight east from Great Bend for a distance of 8 or 9 miles along the township line. The view eastward was over a broad, level valley terminated by a low range of sand-dunes in Rice county. The horizon westward was limited by the high plains of Rush county, 24 miles distant, terminating southward at Pawnee Rock, about the same distance. This Rush county plain was a little higher above the river than the bluff back of my house. From my point of observation it gave a perfectly level sky line.

Observations in the morning were taken at seven o'clock, or a few minutes before, which, during winter, was always at or before sunrise. Observations on temperature at the summit, middle and base of the hill were frequently made, especially if there were any mirage. I quote from the record made during a remarkable mirage that occurred on the morning of January 28, 1877: Temperature at station on hillside back of the house, at 6:50 A. M.,  $15^{\circ}$ . Taking a thermometer graded exactly like the one in the shelter, I found the temperature of the valley, 25 feet lower, at 6:51, to be  $6^{\circ}$ ; at bottom of watercourse, 10 feet lower still, at 6:52,  $2^{\circ}$ .

Returning to the station quickly, the temperature rose as the hill was ascended. At the station, at 6:55, the instrument in hand at first showed  $16.5^{\circ}$  while the instrument in the shelter stood at  $18^{\circ}$ . Both instruments, however, soon stood at  $18^{\circ}$ . It was then noticed that Great Bend, 6 miles distant, was unusually distinct and near, and the hills of Rush county appeared over the roof of the court-house at Great Bend, something never before seen. It was realized that something unusual was occurring right then; but, intent upon taking an observation on temperature at the summit and getting back to the station at seven o'clock, I started up without dwelling on the scenes.

However, 25 feet further up I was interrupted by a most unusual phenomenon.

Just over my head I approached a level crystal surface, as though I were walking in a sea of liquid air and about to emerge from it. This extended out over the valley to the west as far as the eye could reach, and seemed to cut the court-house at Great Bend at its middle elevation. Part of the court-house and other buildings were reflected in the sky and upside down. The city was also partly reflected from below, showing that there was another stratum surface of cold air in the bottom of the valley.

As soon as my head emerged above the surface of the cold-air stratum the city disappeared as if by magic; but the hills beyond could be seen still more clearly than before. The tower of the court-house and two or three church steeples and the belfry of the school-house were about all that could be seen of the city. Stooping a little so as to look from under the stratum surface, Great Bend was there as before, triply to be seen; but on straightening up, every time it would immediately vanish. On standing up, Larned, 28 miles distant, immediately came into view and was easily recognized; and even Garfield, 8 miles further, could be made out. Standing thus and holding the thermometer overhead, the temperature was noted at 25°. Placing it at the feet it dropped to 20°. This performance was repeated several times, always with the same result or with only slight variation.

Hurrying to the top of the bluff, the temperature was found to be 32°; and, on climbing to the top of a heap of stones on the summit and holding the instrument at arm's length overhead, the temperature was found to be 33°.

Then a most extraordinary phenomenon presented itself. The city of Atlanta, in Rice county, about a mile south of the present city of Lyons, 24 miles distant, and the hills to the north and east, were all in plain view over the tops of Plum Butte and other sand-hills in Rice county. Superintendent Stephenson's great big shell of a house on the high prairie, 8 miles north of Atlanta, was identified. A long rift of sky appeared in the eastern horizon; and what at first appeared to be a cloud, but quickly appeared to be land much farther away than Rice county, lay in a low flat cloud half a degree or so in diameter, about one-third of a degree above the eastern horizon. The roseate glow of both horizons showed that the sun was very close to the edge. The upper horizon was the redder.

It still lacked nearly ten minutes of sunrise; and I watched, forgetting all else, to see the sun appear in the rift between the two horizons. To my surprise he began to appear over the upper horizon, fully eight minutes before his time, and looking like a long line

of prairie fire extending north and south along the horizon. He soon appeared fully above the horizon and looked like an enormous elongated red football lying on its side with the ends north and south.

Three minutes of time had passed. Eight minutes of time is equivalent to  $2^{\circ}$  of longitude, amounting in the latitude of Great Bend to 109 miles. Hence the sun was seen at a time when it must have been fully  $2^{\circ}$  below the horizon and ought to be just rising in eastern Marion county, or even Chase or Butler. Presently the rift of sky and the upper horizon disappeared altogether, sun and all, and the true sun began to rise a second time, still about one and one-half minutes before his stated time; but this time only slightly flattened.

Looking to the north over Cheyenne Bottom the entire plain was alive with a wavy, tremulous motion, like hot air rising from a furnace. Atlanta and Larned had now disappeared. The temperature was  $34^{\circ}$  and the show was over.

Passing down to the surface of the upper stratum of cold air, the mirrored appearance was still faintly to be seen; but it was being broken up by a slight breeze flowing from the northwest. At the station at 7:20 the temperature was  $22^{\circ}$ , a rise of  $7^{\circ}$  in about half an hour. Passing on down into the valley the temperature was found to be  $15^{\circ}$ , a rise of  $9^{\circ}$ . Continuing into the creek bottom the mercury dropped to  $10^{\circ}$ , a rise of  $8^{\circ}$  from the first observation. This showed that the breezes stirring on the hill had not yet reached the bottom.

Mirage of this character is usually most noticeable, not when the temperature is so low as in the case noted, but when the temperature is close to the freezing-point. Then the cold frosty air flows into the valley, leaving the warm air on the high lands. That is why frost appears first in valleys and low grounds, and why there is less frost in spring and fall on a hilltop. Perhaps that was true in the case noted, as shown by the temperature taken from the stone heap on the summit.

One of the most notable cases of refracting mirage that has come under my observation was one that occurred on the night of November 2, 1899, at Topeka. This was not known as a mirage. It would have passed entirely unnoticed had not a preconcerted arrangement been made over a wide extent of territory in order to determine the visibility of certain phenomena.

There were to be some fireworks burned in Topeka in honor of the return of the Twentieth Kansas from the Philippines. At my solicitation, the Topeka *Capital* offered a series of prizes to the ladies of the country surrounding Topeka who should be fortunate enough to see the fireworks at the greatest distance. Therefore, thousands of

people in the counties surrounding Shawnee were on the watch at the appointed hour.

Hundreds of letters were sent in in the next two days, and some of them from astonishing distances. The farthest was from a lady at Salina, 104 miles distant in an air-line, who claimed to have seen reflections in the sky. The letters were all turned over to me for digestion and disposal. This required my best mathematical ability in order to do justice to all and wrong to none.

The topographical maps of the United States Geological Survey were used to determine altitudes.

Topeka lies in a platter-like valley, whose rim is from 10 to 25 miles distant and raised from 200 to 370 feet above the city. The city itself is located on several gentle ridges, averaging about 75 feet above the level of the Kaw river. The base of the capitol building is about 90 feet above the river.

The fireworks were "let loose" from the capitol building and state grounds at 8:20 to 8:45 P. M. They consisted mainly of Roman candles, red fire, sky-rockets, and bombs. The candle balls were fired to an elevation of 75 to 150 feet from the landing at the base of the cupola on top of the dome of the state-house, 280 feet from the ground, being an elevation of 350 to 430 feet. The red fire was burned on a ledge at the base of the dome, 190 feet from the ground. The rockets were fired from a balcony 30 feet lower, and, while fired at somewhat of an angle, were supposed to reach an elevation of 650 to 700 feet. The bombs, which were called "thousand-foot," were fired from the ground, and were supposed to reach an elevation of 650 to 800 feet. The bombs on bursting displayed fires of various colors.

Ordinarily the bombs and rockets should be seen to a distance of 25 to 30 miles. They were seen in every direction very much farther than that. Colors were generally distinguishable to a distance of 27 miles. The greatest distance from which colors were distinguished was 29 miles. This, however, did not depend upon mirage, but upon personal peculiarities.

Toward the northeast the fireworks were seen at Nortonville, 34 miles distant, north  $38^{\circ}$  east. Horizon toward Topeka dead level or depressed  $1'$  of arc below a level. Height of fireworks required, 700 feet. This showed no evidence of mirage, or at most only very slight.

Toward the northwest the greatest distance reported was Soldier, 39 miles distant, north  $27^{\circ}$  west. Horizon toward Topeka depressed  $4'$  of arc below a level. Height of fireworks required, 754 feet. This was normal; the fireworks should have been seen farther in the same direction but for the intervention of the hills.

They were seen at Edgerton, Johnson county, 42 miles distant,



south  $60^{\circ}$  east. From here the fire-balls were seen to rise just barely above the horizon, rest for a moment or move in a curve, then fall back. This observer was not the farthest.

They were seen from an upstairs window of the poor-farm at Garnett, Anderson county, 56 miles distant in an air-line, south  $27\frac{1}{2}^{\circ}$  east. Horizon toward Topeka elevated  $2'$  of arc above a level. Necessary height of fireworks, 2210 feet. This is a most astonishing thing, and is what caused the question of mirage to be instituted. The reliability of the observers had to be first established; then the chance of their seeing something else, as shooting stars or fireworks at some intermediate point, was considered and rejected; finally the question of mirage was considered and established beyond question. The conditions were favorable: A clear sky; a lulling of the wind to about one to two miles per hour; a slight frost; temperature  $34^{\circ}$  to  $28^{\circ}$ ; rapid radiation from the earth and consequent settling of the cold air into the valleys. Under these conditions there surely was mirage; though it could not have been known or noticed except under the peculiar combination of circumstances that then prevailed. The accounts of these observers were confirmed by numerous other letters received from Lyndon, Quenemo, Pomona, Williamsburg, Waverly, and Lebo, from 30 to 48 miles distant.

Greatest distance southwest was at Ottumwa, 6 miles northwest of Burlington, Coffey county, 52 miles distant, south  $5^{\circ}$  west. Horizon toward Topeka elevated  $2'$  of arc. Necessary height of fireworks, 2034 feet. This is another case that shows the effect of mirage. This place happens to be in the same end of the oval of vision and is governed by the same conditions as Garnett.

Whether this mirage was of the pure refracting kind cannot be told. A ball of fire may be inverted without changing its appearance. It is probable, however, that to observers in Anderson and Coffey counties, some low-lying, light, fleecy clouds, not visible at Topeka, overhung Osage and western Franklin counties, and reflected the fireworks into the lower counties. This is the more probable from the statements of the observers, who were almost unanimous in saying the fireworks appeared at a height of  $2^{\circ}$  to  $3^{\circ}$ . The fireworks were not seen at Ottawa or Princeton, well within the circle of vision.

A full description of this remarkable phenomenon may be seen in the Topeka *Daily Capital* of November 19, 1899.

This map shows the area over which the fireworks could be seen in favorable localities. This area covers 6000 square miles, equal to about ten counties. (Map not reproduced.)

It is to be observed that the longest diameter of this oval (87 miles) lies precisely in the direction that the wind blew that night;

and the longest extension of it (56 miles) is with the wind. How much the wind has to do with modifying the form of the circle of vision I do not know. Ordinarily I would expect the longest diameter of this circle to be east and west, in accordance with the valley of the Kaw.

These observations show that mirage occurs often; always occurs at night, when the wind is calm, the sky clear, radiation strong, and the temperature falling. It usually disappears as soon as the temperature begins to rise in the morning.

Ordinarily in Kansas, with its lovely skies and transparent air, we do not have to "wait until the mists gang awa'" in order to be able to "see as far as the mune."